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Seasonal Variation in Wood Permeability and Stem Moisture Content of Three Rocky Mountain Softwoods

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Time of year does not affect wood permeability but does affect water content of the trees, especially the sapwood. The water contents were highest during the winter.

Keywords: *Picea engelmannii, Pinus contorta, Pseudotsuga menziesii,* wood permeability, tree water content.

The Rocky Mountain region has a considerable potential for the production of poles from lodgepole pine (Pinus contorta), Engelmann spruce (Picea engelmannii), and Rocky Mountain Douglas-fir (Pseudotsuga menziesii). These species are not being used in proportion to their availability, however, because of (1) thin sapwood, (2) heartwood that is difficult to treat, or (3) incomplete preservative penetration of those with thicker sapwood.

This research was designed to gain information on the characteristics of these species that influence treatability. Specific factors studied were seasonal variations in longitudinal permeability and stem moisture content. Permeability directly influences flow of preservatives into wood, while high moisture content, especially in the sapwood, retards the entry of oil-borne preservatives. Any seasonal variation would therefore be of significance in the treating process.

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Methods

Field Procedure

Ten trees of each species were sampled (table 1). The Douglas-fir were growing with ponderosa pine in a stand about 10 miles west of Fort Collins, Colorado. The lodgepole pine and Engelmann spruce were sampled at the Fraser Experimental Forest near Fraser, Colorado. The only criteria for selection were that the trees be of suitable size and shape for poles.

Five trees of each species were sampled during each of four physiological "seasons": (1) spring during the growing season, (2) summer, (3) fall after dormancy but before freezeup, and (4) winter during freezeup. Another five trees of each species were sampled monthly during the growing season. Sampling for stem moisture and permeability was extended into the second year to determine any annual change. Two increment cores of 0.5-inch diameter were extracted from equally spaced and randomly assigned positions around the stem at both the 3- and 5-foot levels above the ground. The cores were bored to a depth approaching the pith. One core from each level was cut into outer and inner sapwood and heartwood segments, and wrapped in heavy-

Stands where species were sampled:

Douglas-fir, west of Fort Collins.

Engelmann spruce, on Fraser Experimental Forest.

Table 1.--Growth characteristics of trees sampled

Species	Diameter at breast height		Age		Growth rings in center inch	
	Ave.	Range	Ave.	Range	Ave.	Range
	Inches		Years		Number	
Douglas-fir	10.77	9.3-12.2	75	64-108	32.4	26-38
Lodgepole pine	11.06	7.8-13.4	216	156-242	51.6	36-92
Engelmann spruce	12.41	9.7-16.2	139	100-187	25.3	14-38

Lodgepole pine, on Fraser Experimental Forest.

duty foil. Segments were weighed to the nearest 0.001 gram within 4 hours, ovendried at 103° C., and reweighed. Moisture contents were calculated on an ovendry basis. The other two cores were placed in glass vials filled with distilled water and immediately airmailed to the Forest Products Laboratory at Madison, Wisconsin, for permeability measurements.

Mechanical Preparation of Permeability Samples

The submerged cores were at 38° F., and green permeability measured within 1 to 2 weeks.

Four permeability test plugs—outer sapwood, inner sapwood, outer heartwood, and inner heartwood—each approximately 0.250 inch in diameter and 0.35 inch in the fiber direction, were cut from each core (fig. 1).

Distance from the cambium to the center of the sample plug was recorded, since it has been established that permeability decreases with increasing distance from the cambium (Comstock 1965). Liquid permeability was measured while each specimen was green; the specimen was then conditioned to approximately zero moisture content and the permeability to nitrogen gas was determined.

Permeability Measurement

The general equipment and procedures used to measure gas and liquid permeability have been previously described (Comstock 1965, 1967). A rubber stopper, drilled out in the center to hold the specimen, was placed in a chamber tapered at the sides to conform to the angular bevel of the stopper (fig. 2). A plunger designed to apply pressure was placed on top of the stopper. When the cap for the holder was tightened, the plunger was forced against the rubber stopper. This in turn forced the stopper further down in the tapered chamber. The compression of the stopper effectively sealed the specimen so that flow was possible only through the wood structure. Water permeability was determined over a 3-minute interval to insure that the apparatus was working properly and that contamination of the permeating water was not a factor in the results.

A tube of plexiglass providing a maximum hydrostatic head of approximately 80 centimeters of water was used to maintain flow through sapwood permeability plugs. After the liquid passed through the test cell, the flow rate was measured on a Brooks rotometer [3] to an accuracy of ± 1 percent.

The flow rate through heartwood was more difficult to determine because heartwood has relatively low permeability compared to sapwood. Consequently, a graduated pipette was used in place of the rotometer. Pressure was applied to the water in the system with nitrogen regulated by a standard pressure regulator. Flow was established by recording the time of advance of liquid into the graduated pipette.

After the liquid permeability was measured, the specimens were dried and nitrogen gas

[3] *Trade and company names are used for the benefit of the reader, and do not constitute endorsement by the U. S. Department of Agriculture.*

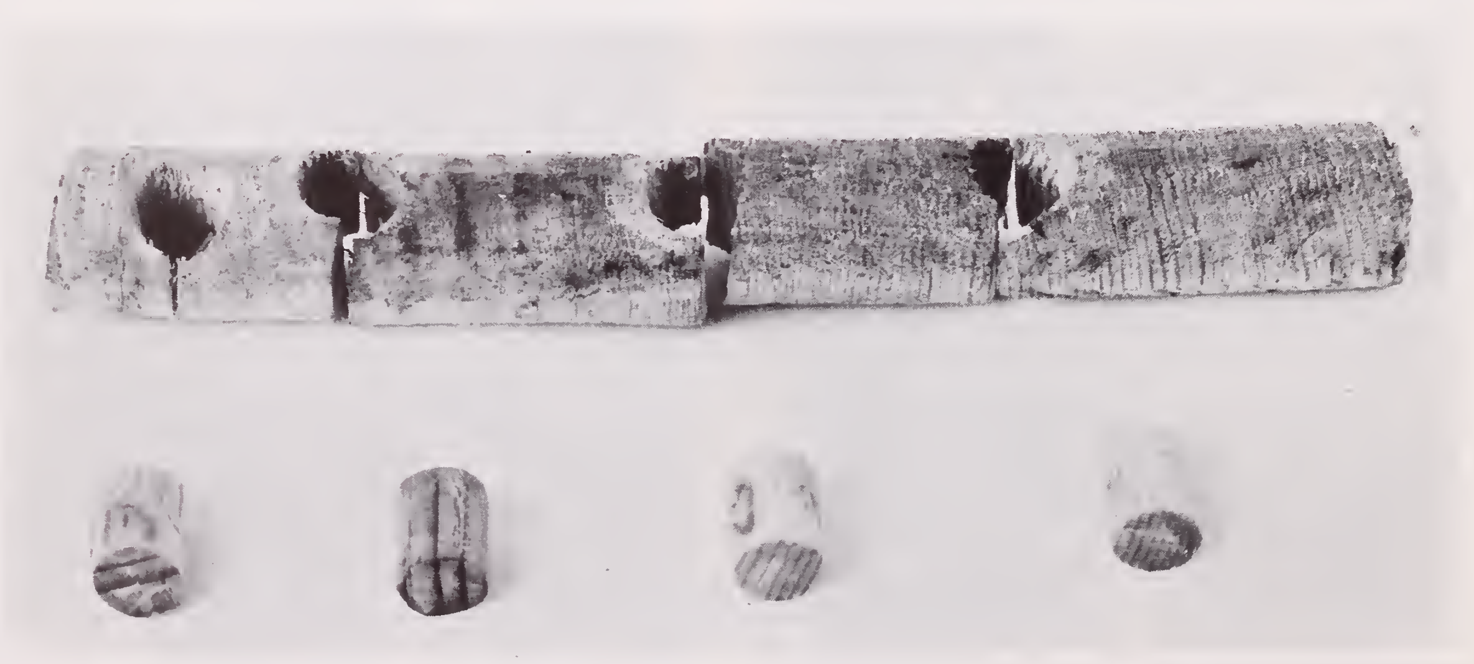

Figure 1.—Four permeability specimens cut from an increment core.

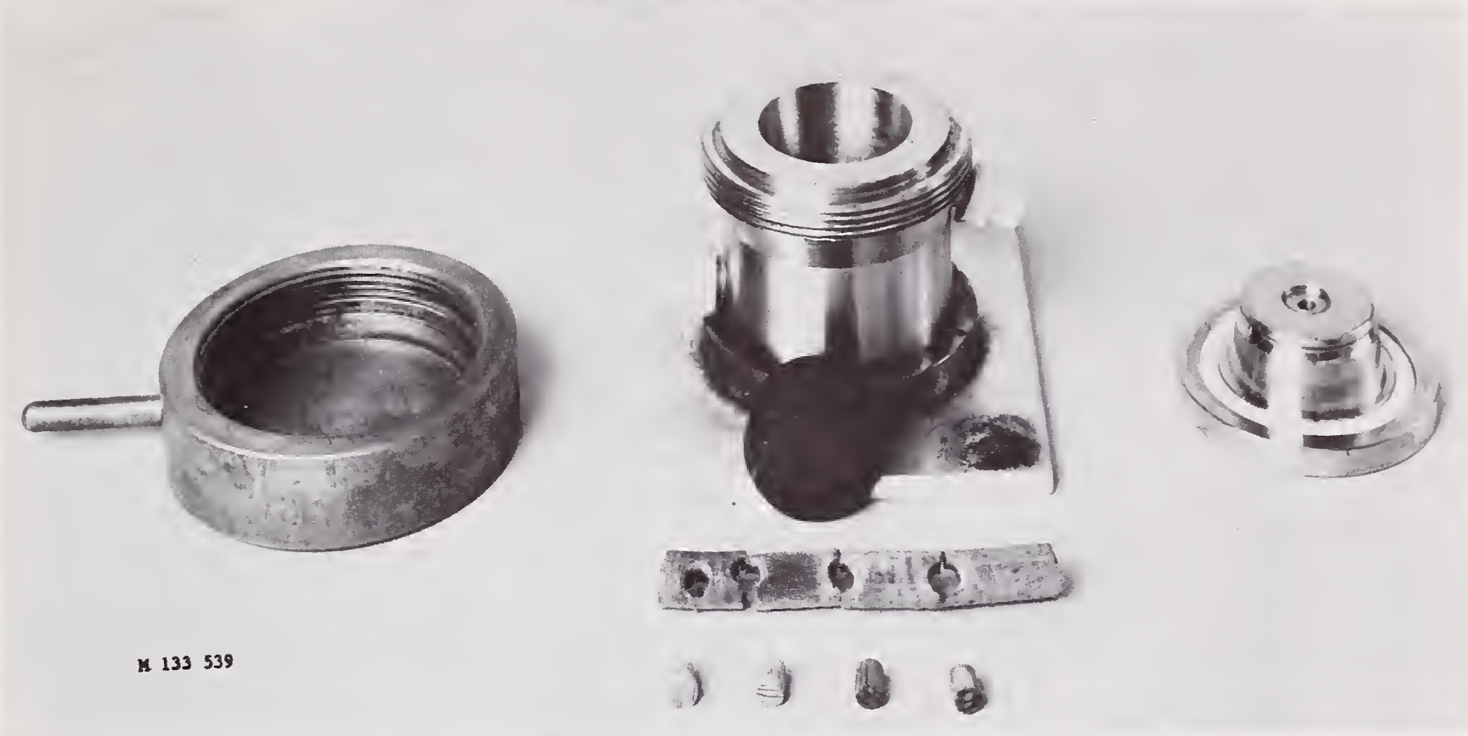

Figure 2.—The specimen is placed in the hole in the rubber stopper (center), the stopper is placed in the tapered housing (upper center), the plunger (right) is placed on top of the stopper, and finally, the cap (left) is tightened on the housing to force the plunger against the stopper, thus sealing the stopper tightly around the specimen.

permeability was measured. Details of the method are described by Comstock (1965). In general, the apparatus consisted of a nitrogen tank, a pressure measuring and regulating system, the specimen holder (fig. 2), and a series of rotometers. Gas permeability was measured at atmospheric pressure on the downstream side, while maintaining a pressure drop through the specimen of approximately 40 centimeters of mercury. The gas permeability values were not corrected for slip flow. Slip flow increases gas permeability slightly (Comstock 1967), but not enough to be of importance in this study.

Results

Permeability

Season did not have an apparent effect upon liquid or gas permeability. The data showed considerable variation among trees with a coefficient of variation of about 33 to 50 percent, but most of this must be attributed to factors other than season.

The liquid and gas permeabilities of the sapwood for all species were greater than those for the heartwood (table 2). The liquid permeability of the outer sapwood for all species was greater than that for the inner sapwood, but the heartwood portions did not differ appreciably. Gas permeabilities of the outer and inner portions of neither sapwood nor heartwood differed appreciably.

Stem Moisture

The moisture content of the outer and inner sapwood for the three species varied significantly with the "seasons." The sapwood moisture contents were the highest during the winter freezeup (table 3). Moisture contents of the trees during August 1968 were not significantly different from those of August 1967. Both the outer and inner heartwood of Douglas-fir showed no real change in moisture content throughout the year. These results agree with those reported for Engelmann spruce and lodgepole pine sapwood during the winter and fall (Swanson 1967), for Douglas-fir sapwood and heartwood (Parker 1954), and for ponderosa pine sapwood (Yerkes 1967).

Differences in moisture content between the two spring growing seasons and between months during the growing season are probably affected by current weather and moisture regimes (table 3).

Regression analyses showed no significant relationship between permeability and water content, either within sampling periods or over the duration of the study.

Table 2.--Permeability of outer and inner sapwood and heartwood of Douglas-fir, lodgepole pine, and Engelmann spruce

Permeability by species	Outer sapwood		Inner sapwood		Outer heartwood		Inner heartwood	
	Mean	Standard error	Mean	Standard error	Mean	Standard error	Mean	Standard error
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Liquid permeability:[1]								
Douglas-fir	2.796	0.195	2.031	0.182	0.006	0.001	0.004	0.001
Lodgepole pine	3.029	.148	2.287	.129	.001	.0007	.001	.0004
Engelmann spruce	3.570	.287	2.042	.246	.007	.006	.010	.005
Gas permeability:[1]								
Douglas-fir	.035	.004	.032	.003	.023	.003	.020	.003
Lodgepole pine	.077	.006	.076	.005	.037	.002	.038	.003
Engelmann spruce	.079	.007	.069	.006	.032	.004	.034	.006

[1]Liquid permeability:

$$Darcys = K = \frac{QL_n}{A\Delta P}$$

Gas permeability:

$$Darcys = K = \frac{QL_n}{A\Delta P}\frac{p}{p'}$$

where

K = permeability (darcys)
Q = flow rate (cubic centimeters per second)
A = flow area (square centimeters)
L = flow length (centimeters)
ΔP = pressure drop (atmospheres)
n = viscosity (centipoise)
p' = mean absolute pressure within the specimen (atmospheres)
p = pressure at which the flow, Q, is measured (atmospheres)

Conclusions

Permeability of sapwood of the three species is greater than that of the heartwood; therefore sapwood-heartwood proportions would be expected to affect treatability.

Although time of year does not affect permeability, it does affect water content of the trees, especially of the sapwood. Since moisture content of the wood for most treating methods should be near or below the fiber saturation point (Hunt and Garratt 1953), trees harvested in winter would have to lose proportionately more water to be as treatable as trees harvested during the growing season.

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Table 3.--Seasonal variation in moisture content of outer and inner sapwood and heartwood of Douglas-fir, lodgepole pine, and Engelmann spruce

Species, by period of measurement	Outer sapwood		Inner sapwood		Outer heartwood		Inner heartwood	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	Percent of ovendry weight							
DOUGLAS-FIR:								
Spring growing (1967)	148	24	141	27	28	1	29	1
Summer	126	18	120	25	27	2	28	2
Fall dormancy	129	20	118	20	29	1	30	1
Winter	155	10	150	16	31	1	32	1
Spring growing (1968)	133	19	122	17	30	2	31	2
Summer	130	19	115	36	28	1	31	1
Month of growing season--								
May (1967)	124	23	115	23	29	2	28	1
June	118	16	119	18	28	1	29	1
July	117	19	118	17	28	1	29	1
August	108	27	101	23	26	1	28	1
September	119	15	114	17	28	2	29	2
August (1968)	113	28	108	22	28	1	29	3
LODGEPOLE PINE:								
Spring growing (1967)	138	25	138	22	35	6	43	8
Summer	145	22	144	16	42	20	48	13
Fall dormancy	161	18	147	31	39	14	47	15
Winter	173	18	164	16	43	9	68	27
Spring growing (1968)	127	30	131	17	36	6	47	11
Summer	150	29	150	21	42	20	55	16
Month of growing season--								
May (1967)	129	22	135	15	38	14	46	15
June	139	20	136	20	33	4	46	18
July	136	17	139	22	47	20	62	31
August	122	14	128	17	36	5	49	16
September	134	25	126	27	39	12	50	20
August (1968)	125	20	137	18	35	3	46	9
ENGELMANN SPRUCE:								
Spring growing (1967)	174	12	169	25	39	10	46	17
Summer	167	9	158	17	42	15	39	9
Fall dormancy	173	19	152	32	43	6	43	10
Winter	191	21	168	43	48	15	43	8
Spring growing (1968)	155	12	134	30	39	12	37	10
Summer	159	31	148	29	40	6	39	10
Month of growing season--								
May (1967)	185	25	171	22	48	16	43	9
June	165	22	156	30	45	21	47	28
July	176	17	178	27	44	10	45	23
August	170	20	160	28	47	14	47	14
September	170	19	177	19	40	5	38	4
August (1968)	167	20	161	29	45	13	46	10

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